Nova-NOTE- Scint-93

Module Leak Testing

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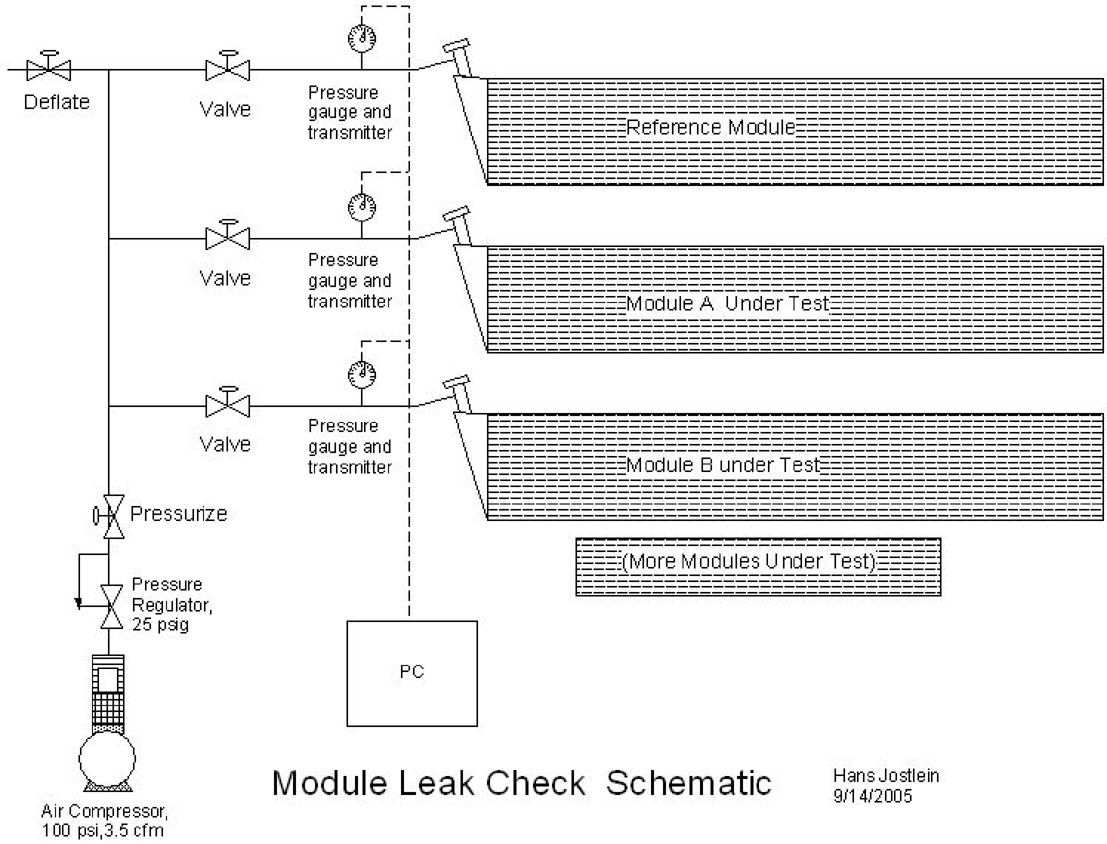
Abstract
We propose a method for leak testing completed modules.
We find that a sensitivity of 1 liter of oil per year per module can be achieved.

Introduction
NOVA will be assembled from 23,808 extrusions, each 1.3064 m wide, 66 mm thick, and 15.8 m long, with a volume of 1167 liter each.
The modules will be assembled at several factories.
The assembly process includes fiber installation , and terminates with the installation of the bottom closure plate and the top manifold closure.
Leaks are most likely to occur at factory-made seals, which include the closure plate and manifold seams, and the fiber block.
We propose a leak checking method and estimate its sensitivity to leaks.

Leak Test Method
The module volume is pressurized and its pressure is recorded for the duration of the check time, which might be overnight. We assume a 10 hour check time here.



There are complicating factors in interpreting the pressure curve:
--Atmospheric pressure changes
--temperature changes
--plastic creep of the module under test.
The first two are monitored by recording the pressure curve of a reference module in the same room. Creep effects will be discussed further down.

Choice of Test Pressure

The largest hydrostatic operating pressure, 19 psig, occurs at the bottom of vertical extrusions. This sets the scale for a test pressure. One may consider using 25 psig if one wants to be a little conservative. The test sensitivity to leaks is almost independent of the choice of test pressure, except in cases where leaks open up due to mechanical stresses stemming from the pressure forces.
It is important to realize that the maximum pressure occurs only at the bottom closure, and that this pressure acts directly on the bottom closure plate whence it is transmitted directly to the floor. However, additional forces try to swell the extrusion and put stress into the bottom plate glue joint. This motivates the use of a substantial test pressure.
The test pressure also stresses and deforms, by creep, the cell geometry.
We do not wish to impart an unacceptable permanent deformation to the cells. On the other hand there is a benefit from pre-distorting the extrusions to a shape that they will

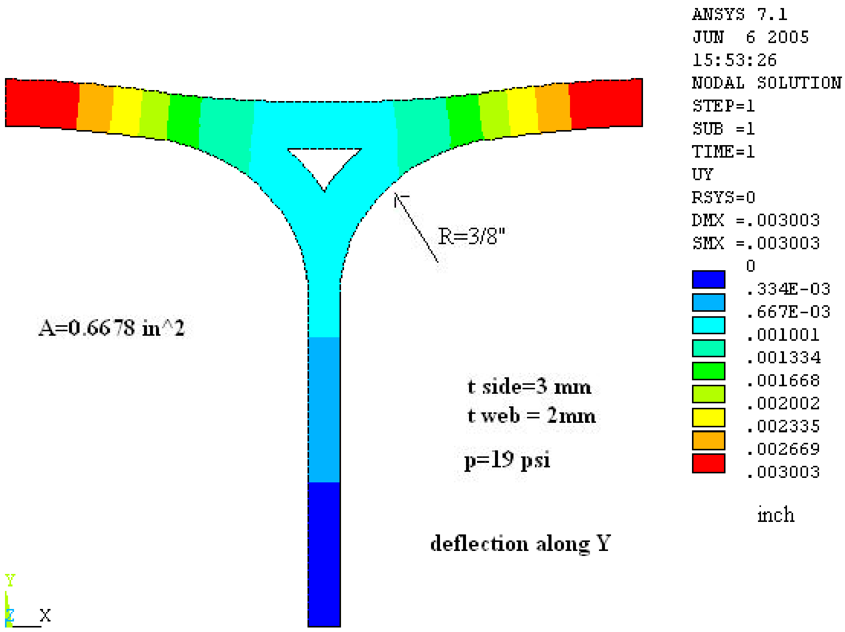
take on eventually from long-term creep. By doing so we can hope to avoid glue stress arising from the creep deformation at a later time. This can be accomplished by choosing a combination of pressure and test time that meets that condition. I have not yet calculated this.
Another upper pressure limit would be set in a case where the active manifold can, by design, only support a reduced pressure.

Sensitivity Calculation

We assume here that any leaks are small enough to result in laminar flow. In this case the volumetric flow rate will be proportional to the inverse of the fluid viscosity.
The flow rate for air will be larger than that of scintillating oil.
We find at
http://hypertextbook.com/physics/matter/viscosity/
a viscosity for air of 17.9 micro Pascal seconds, and for light oil of about 50 milli Pascal seconds.
I will show below that one can hope, at best, to be sensitive to leaks of about 1 liter of oil per year per extrusion. I use this rate to calculate the size of the expected test signal.
For our 1167 liter module volume, and 25 psig maintained for 10 hours, we expect a pressure drop of 0.07 psi, corresponding to 1.1 inches water pressure.
To measure this change with a 10% error, we need a pressure gauge with a repeatability of (0.11" WP / 25 psig)= 0.7 parts in 1000. Gauges of this repeatability are commercially available.

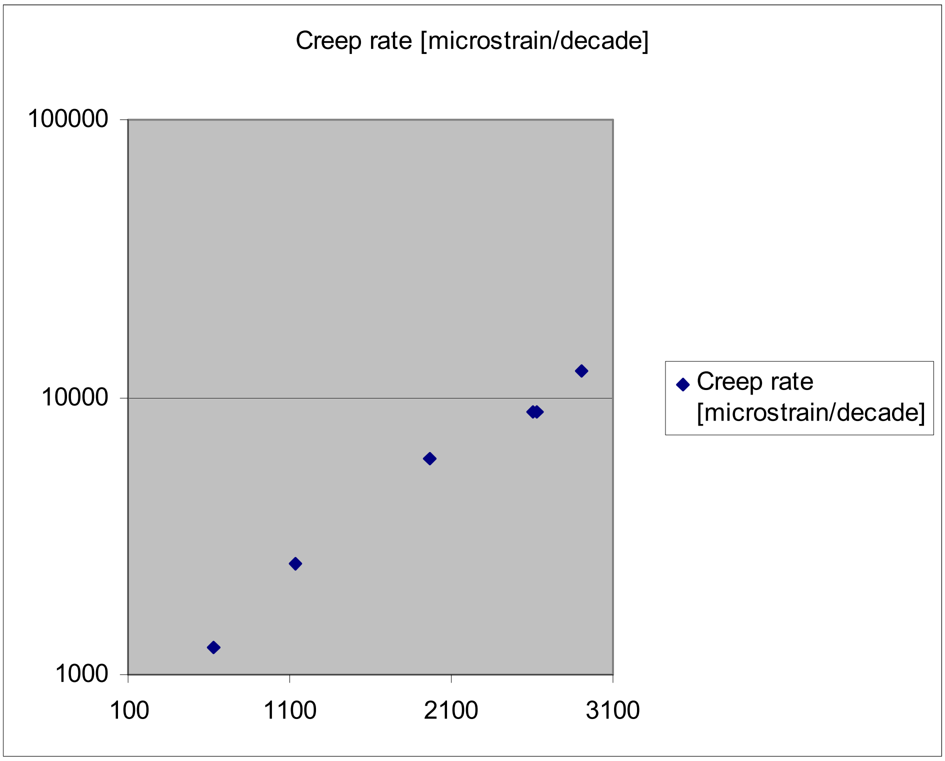
Creep Effects

The "organic" cells of size 38mm x 60 mm internal change their depth elastically by 0.006 inches at 19 psig To get a handle on expected creep during the test, we make the assumption that the cell stresses are designed such that the creep after 30 years (175k hours) matches the elastic deformation:



Interior Cell with a 3/8" radius & pocket flat backside

For a logarithmic creep rate, we find that the creep during a 10 hour test is (log(175k / 10) = 3.24 times smaller.
The hydrostatic pressure drops linearly with height, so the average deformation is half the maximum. This over-estimates the creep rate because creep rate increases exponentially by about a decade for each 2300 psi , as shown by the graph from our earlier measurements on the Extrutech PVC:



Neglecting this effect (worst case), and assuming a creep rate proportional to stress, we find a relative increase in cell volume of
(0.006")*(1 /2) * (1/60 mm)*(1/ 3.24) = 0.004
This corresponds to a pressure drop of (0.004)*(25 psig) = 0.1 psig, or 1.63 inches water pressure.
This is larger than the 1.1 inch water pressure sensitivity we used earlier.
However, creep proceeds logarithmically, even at early times, while leaks lower the pressure at a constant rate. It will be possible to separate the two components by fitting the pressure curve.

Conclusion

We propose a simple leak test for completed modules and find that the sensitivity of leak tests is no better than about 1 liter of oil pre year per module.
This sounds rather disappointing, but the bad news is tempered by the following considerations:
-- while we do not yet know the statistical distribution of leak sizes, one can hope that leaks are either large enough to be detected easily, or too small to worry about

--leaks are far more likely to occur at the rather complicated active manifold than at the simple bottom plate. The active manifold is only subject to modest pressure , less than 1.6 psig
-- The horizontal extrusions are subject to no more than 1.6 psig

On the other hand we must expect a number of slow leakers, and design the secondary confinement system to collect this oil properly.